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MUSHROOM CITIZEN SCIENCE: From Species Lists to Mycoflora 2.0

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This report examines what mushroom clubs have been doing to voucher and sequence specimens since the 2012 meeting of the North American Mycoflora Project, identifies challenges encountered, and describes the Mycoflora 2.0 Project designed to enlist citizen scientists and professionals in creating online, geographic-based mycofloras.

The tagline of the North American Mycoflora Project – "without a sequenced specimen, it's a rumor" – reflects the importance of two activities that are central to 21st century mycological science: vouchering specimens in established fungaria, and obtaining genetic information by sequencing DNA. The traditional practice of amateur mushrooming is to collect specimens, try to identify them, create species lists … and then discard the specimens. That's similar to the model of amateur birders who create unvouchered species lists at Christmas bird counts. Amateur birding is often held up as the quintessential citizen science activity, but mushroomers have an advantage in that specimens can be readily collected and preserved.

Since I have scientific training (in insect ecology) and an interest in citizen science, I wondered what mushroom clubs were doing to voucher and sequence mushrooms. On behalf of the North American Mycological Association's Mycoflora Committee, I queried clubs through a survey and direct contact. **What I found was a delightfully chaotic variety of projects, notable for the diversity of protocols employed as well as the lack of coordination between them**. The projects demonstrate considerable potential while highlighting significant challenges. The purpose of this paper is to describe club vouchering and sequencing projects, assess challenges, and report on a proposed project, called Mycoflora 2.0, to make vouchering and sequencing simple and inexpensive for clubs and organizations that want to do it.

North American Mycoflora Project

A stimulus for sequencing activity and a renewed push for vouchering appears to be the North American Mycoflora Project. The Project is a collaboration between professional and amateur mycologists that aims to create online compendia for macrofungi in defined geographic areas, similar to floras for plants and lichens. Macrofungi are fungi that are easily visible without a microscope -- essentially mushrooms, polypores, truffles, corticioid fungi, and Ascomycota with large fruiting bodies (Bruns and Beug, 2012). The goals envisioned by Vellinga (2013) for a North American Mycoflora include "keys, descriptions, accompanied by photos, notes of the fresh specimens, data on habitat, location and date, and with DNA sequence data [and] available on the web, portable, free, and easy to update."

NAMF -T-shirt

An early advocate for a North American mycoflora was mycologist Tom Bruns of the University of California at Berkeley (Bruns, 2011; see also Matheny and Vellinga, 2009). Bruns and colleagues secured National Science Foundation funding for a networking project that had enough funds left over for a meeting in 2012 at Yale University. The meeting included 75 leading professional and amateur mycologists from the Mycological Society

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UPCOMING FORAYS & OTHER EVENTS

The events page of *The Mycophile* publicizes forays and events of NAMA affiliated clubs which may be of interest to our members. If you would like to list your club's next big event, contact Dianna Smith, Editor: mycophile@namyco.org.
Include date, location, brief description, link for information, and host organization name.
To post your event on the NAMA website, contact the webmaster: webmaster@namyco.org.

JULY 21-22: West Virginia Mycological Club (WVMC) Shelly Conrad Memorial Foray, Dry Fork, West Virginia with Gary Lincoff, Walt Sturgeon, Tom Volk and other to be announced mycologists. Registration will be available soon at https://www.wvmushroomclub.net.

JULY 27-30: Annual NEMF Sam Ristich Foray, Stratton Mountain, Stratton, Vermont. Registration is open. Gary Lincoff is Chief Mycologist. See www.nemf.org to register

AUGUST 10-13: NAMA Regional Foray in Arizona with Dr. Scott Bates and Dr. Rick Kerrigan. Registration opens soon. https://www.arizonamushroomsociety.org/event-2469863

SEPTEMBER 1-4: COMA's Clark Rogerson Foray will be returning to the completely refurbished Camp Hemlocks in Hebron CT. Registration opens in June. See www.comafungi.org.

SEPTEMBER 7-10: NAMA Northwoods Foray at Lakewoods Resort, Lake Namakagon, Wisconsin. Registration is open. Consult www.namyco.org to register.

SEPTEMBER 24-28: WILDACRES *AMANITA* Workshop with Dr. Rod Tulloss. Contact Glenda O'Neal glendakoneal@yahoo.com, or (423) 863-2742.

SEPTEMBER 28- OCTOBER 1: WILDACRES 2017 Foray with mycologist Brandon Matheny and others. See http://www.wildacres.org./ To register contact Glenda O'Neal (see above): Download registration form at http://www.namyco.org/events.php.

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NEW EDITOR NEEDED for *THE MYCOPHILE*!

I have decided to step down from the position of editor of *The Mycophile* to spend more time with grandchildren, studying, teaching and assisting my local club, the Pioneer Valley Mycological Association, in our involvement with the Mycoflora 2.0 Pilot Project. I am pleased to have been able to produce over the past five years a fairly varied 24 page newsletter for NAMA members every two months. I credit my contributors as well as my astute proof-readers Michael Beug, David Rust and especially Steve Trudell for their collective efforts to oversee and ensure the quality and accuracy of the material presented. My final issue will be the September-October publication. **Please contact me or David Rust if you think you might like to become editor of *The Mycophile*. The position may be perfect for someone who is or was editor of a local NAMA affiliated club.** I will do whatever I can to enable you to get up to speed.

Dianna Smith

(*Continued from p. 1*)
of America (MSA; professionals) and the North American Mycological Association (NAMA; amateurs). Meeting presentations are documented at www.northamericanmycoflora.org and several articles summarize the event (Bruns, 2012; Bruns and Beug, 2012; Vellinga, 2013).

Unfortunately the Mycoflora Project has not gained traction among professional mycologists since the 2012 meeting. In part this is due to lack of funding, but it may also reflect a limited concept of the potential role of amateur mycologists, which is the subject of this paper. The 2012 meeting stimulated considerable interest within mushroom clubs in vouchering and sequencing. Whether motivated by accurate identification of edible, medicinal or psychedelic mushrooms, by the possibility of finding new species, or by fascination with fungal diversity, many mushroom enthusiasts seem eager to make their endeavors more scientific. Some clubs hosted talks and workshops (like the New Jersey Mycological Association's 2014 DNA Workshop) that have not yet resulted in active projects. Other clubs launched a range of projects, many described here.

Methods

NAMA is affiliated with 80 mushroom clubs that have approximately 10,200 members combined, not including several large Canadian clubs, according to NAMA president David Rust. Data for this study were gathered initially by outreach to several NAMA clubs known to voucher or sequence specimens. In December 2016 a link to an online survey ("Mycoflora Survey") was sent to 76 club presidents by David Rust. The survey asked about club capacity, foray frequency, vouchering and sequencing activity, and whether clubs post photos and documentation to the Internet. Survey responses were amplified by direct contact via phone or email with club members responsible for vouchering or sequencing.

Thirty-eight of the 76 clubs contacted responded to the Mycoflora Survey (50% response rate), and four additional clubs were researched for a total of 42 clubs. Thirty-seven of those clubs are in the US, the other five in Canada. Membership in clubs surveyed ranges from 10 to more than 1,200 members. Dues range from $0 to $35 USD per year for individuals. The number of specimens identified on all forays in the past year varied from a few dozen to many hundreds. Interestingly, several active clubs (e.g., Long Island, Santa Cruz, Asheville) report lifetime species lists of around 1,000 species identified. (This was not a survey question.)

The survey sought to determine whether and how clubs post information to the Internet. Posting photo-rich observations to sites such as Mushroom Observer, iNaturalist and Flickr is important to scientific documentation. But high-quality citizen science needs to make information accessible to scientists around the world. Professional mycologists seeking vouchered specimens in North America increasingly search on MycoPortal, which recently completed digitizing almost 2 million records of macrofungi. The fungi are stored in "established" fungaria -- i.e., institutions with curation staff. (Most fungaria in the US are still called "herbaria," a throwback to the time when fungi were considered plants.) The core website repository for DNA sequences is GenBank. Few clubs are currently posting on, or linking to, either MycoPortal, GenBank or UNITE.

This report makes a distinction between two models of mushroom citizen science to emphasize potential for club initiative: "professional-led" and "club-led" projects. Professional-led projects are projects designed and led by full-time mycologists who typically have academic positions, access to university herbaria for vouchering, and funding for DNA sequencing. We use the term "professional" here broadly to include recognized taxonomic experts who do mycology full time but are not paid to do it, as well as external institutions like the National Park Service. For our purposes, the point is that direction and resources come from outside a mushroom club. Club-led projects, by contrast, are initiated, organized and stewarded by amateur club members – albeit usually in partnership with academic mycologists who provide technical expertise and guidance when asked. The selected projects detailed below are not comprehensive; rather they are intended to highlight different approaches to common challenges.

Professional-led Projects

Originated in 1996, "bioblitzes" occur all over the world. In the US they were organized by the National Park Service and the National Geographic Society between 2007 and 2016. They are biological surveys by groups of scientists,

naturalists and volunteers that "attempt to record all living species within a designated area over a continuous time period, usually 24 hours" (Wikipedia). Fungi have been a part of many bioblitzes; those focused specifically on fungi are called "mycoblitzes." When vouchering or sequencing has been done, it is usually by professional mycologists or fungaria professionals.

- **Great Smoky Mountains National Park:** A large and long-running mycoblitz was organized in 2004 by Ron Petersen from the University of Tennessee to sample agarics in the Great Smoky Mountains National Park. Part of a larger bioblitz, the project received significant funding from the National Science Foundation. The project included a 3-day event in conjunction with an annual meeting of the Mycological Society of America in Asheville, NC.

- **Point Reyes National Seashore and Yosemite Mycoblitzes:** Five mycoblitzes occurred at the Point Reyes National Seashore between 2005 and 2007. The events were coordinated by Tom Bruns of the University of California, Berkeley; Darvin DeShazer, founder of the Sonoma County Mycological Association; and David Rust, co-founder of the Bay Area Mycological Society (BAMS) and current NAMA president. BAMS sponsored a "box party" of volunteers in 2007 to process collected specimens for the UC Berkeley Fungarium (UC). Challenges highlighted by the project include the fact that while some specimens were accessioned, others were apparently not and remain in boxes, according to Rust. The Point Reyes project has continued in the form of an annual Fungus Fair co-hosted by the National Seashore and the Bay Area Mycological Society. UC Berkeley mycologists look through the collections and cherry pick unusual or new species on collection day, which they may then voucher or sequence in their lab (David Rust, personal communication). Bruns, Else Vellinga and BAMS also organized a mycoblitz (fungal survey) in Yosemite National Park; many of those specimens were sequenced as well.

Some other mycoblitzes with vouchering include:

- Colorado Mycological Society, Rocky Mountain National Park and Denver Botanic Gardens' Sam Mitchel Fungal Herbarium held mycoblitzes in 2008 and 2009, as well as one in 2012 cosponsored by the National Geographic Society.

- The Metchosin Biodiversity Project has held four mycoblitzes on the south coast of Victoria Island, British Columbia, the latest in 2016.

- The National Park Service and National Geographic have sponsored several bioblitzes that included mycoblitzes, including in 2013 at the Jean Lafitte National Historical Park and Preserve in Louisiana, and in 2016 at Shenandoah National Park in conjunction with the NAMA national foray in Front Royal, Virginia.

Taxonomist-led Projects

Another model occurs when a club helps an expert taxonomist collect species in a particular taxon, which the expert then vouchers and sequences. Two examples involve experts who are professional-level but self-trained in mycology. Rod Tulloss is the leading *Amanita* expert in North America; he is a retired engineer who runs the site www.amanitaceae.org. Another example is Henry Beker who is studying the genus *Hebeloma*. Having completed a monograph on European Hebolomas he is now working on a North American monograph and is seeking help from mushroom clubs in finding specimens, as described in a recent NAMA newsletter article (Beker, 2016). I recently posted a *Hebeloma* observation to Mushroom Observer and within an hour received an email from Dr. Beker offering to arrange a FedEx pick-up "so that you incur no cost." A third example is Michael Kuo's Morel Data Collection Project which ran between 2001 and 2010. Collections were in part crowdsourced from visitors to Kuo's MushroomExpert.com website. They were sequenced and vouchered at the Field Museum in Chicago; 518 observations with photos are posted on Kuo's site. These are only three of many examples of professional or semi-professional taxonomists engaging amateur mushroomers to collect specific taxa.

Survey Results: Clubs Vouchering and Sequencing	
Vouchering	
Club members voucher at home	4
Club members voucher at established fungaria	12
% of clubs with some vouchering	53%
Sequencing	
Clubs conducting club led barcoding	8
Clubs engaged with professional barcoding	12
Clubs with members Interested in sequencing	10
% of clubs sequencing or interested	63%

Club-led Voucher Projects

Mycoflora Survey (Vouchering): Twenty (53%) of 38 clubs voucher at least some specimens, and, of those, 12 clubs (32%) voucher or plan to voucher specimens in established fungaria. It is likely that more amateur mushroom experts save specimens at home, and clubs that voucher may have been more likely than non-vouchering clubs to fill out the survey. There is little pattern as to how clubs post observations to the Internet. Nine clubs post to Mushroom Observer (MO), including one to both MO and iNaturalist and one to MO and MycoPortal (MP). Five clubs post to MP and one to MP and Flickr. Twelve clubs post only to a club website, two post to Facebook, and 11 do not post any observations.

North American Mycological Association (NAMA) Voucher Program: NAMA national forays have been vouchered for 20 years (since 1997), overseen by Patrick Leacock from the Field Museum of Natural History in Chicago. NAMA forays move to a different location every year but all vouchered specimens are accessioned at the Field Museum. The Voucher Collection Program has databased 6,640 records, but not all records have vouchers. Some of the records have been posted to MycoPortal. All of the vouchers "should now be in the Museum collections database online," according to Leacock, "but we still have images to load for half of the forays." Martin Livezey used a bulk uploader developed by Raymond Suelzer to get observations on Mushroom Observer, where voucher photos for the last seven annual forays are posted. For example, the 2016 Shenandoah Foray Species List has 339 observations. Challenges include reporting observations separately to both Mushroom Observer and MycoPortal, without links between those sites.

The **Northeast Bolete Consortium** is an informal network of mushroom enthusiasts from several Northeastern clubs focused on boletes. It was formed in 2015 at the suggestion of Roy Halling of the New York Botanical Garden. Eight experienced collectors (Robert Gergulics, Roy Halling, Renée Lebeuf, Scott Pavelle, John Plischke III, Igor Safonov, Walt Sturgeon, David Wasilewski and Bill Yule) contribute bolete observations to Mushroom Observer, which are linked to the group's Project Page (MO Project 199). The page states: "the project is a concerted effort to collect, document, and analyze two confusing sets of boletes: (A) The various species referred to as 'bicolors'; i.e. those with yellow pores and red-and-yellow caps/stems; and (B) The various species referred to as 'red mouths'; i.e., those with red pores that readily stain blue." Consortium members voucher individually. The Western Pennsylvania Mushroom Club and several members also sequenced selected specimens. WPMC member Scott Pavelle created the Bolete Filter as an online "encyclopedia" of North American boletes that uses images from Mushroom Observer and Consortium members.

Gulf States Mycological Society (GSMS): GSMS president David Lewis has been vouchering along the Gulf Coast for four decades, often with the help of Jay Justice. Lewis has 5,300 collections with detailed notes vouchered at the Field Museum in Chicago (also on MycoPortal); 3,544 specimens from the Big Thicket National Preserve and other East Texas sites at the Tracy Herbarium (TAMU) at College Station, TX (not on MycoPortal); and 394 Russulas and *Cantharellus* vouchered at the National Museum of Natural History in Paris, France.

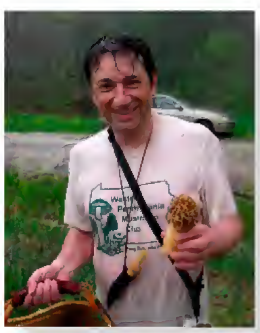
Long Island Mycological Club (LIMC): In addition to being the first club to participate in Henry Beker's *Hebeloma* Project (see above), LIMC has a history of vouchering specimens. The club submitted 75-100 specimens to the New York State Museum (NYS) around 2011, and another 154 specimens to the New York Botanical Garden Herbarium (NY) over the last few years, according to Joel Horman. There is no online record of the NYMS specimens on MycoPortal, indicating that they may not have been accessioned yet – a recurring theme at staff-limited fungaria. NY has accessioned the LIMC specimens and posted them to their on-line database (NYBG Virtual Herbarium) though not yet on MycoPortal "for technical reasons," according to Barbara Thiers.

New Jersey Mycological Association (NJMA): NJMA maintains its own fungarium next to Rutgers University's Chrysler Herbarium (CHRB). The club fungarium has approximately 2,900 specimens accessioned, representing more than 1,000 species, most collected before the year 2000. Club president John Burghardt, with help from Igor Safanov, is working to post the records to MycoPortal in 2017. Burghardt also matched fungarium records with the club's New Jersey species list and generated a list of species which have no fungarium specimens – as targets for future collecting.

Illinois Mycological Association (IMA): In addition to being in charge of the NAMA Voucher Program (above), Patrick Leacock is IMA club president. The club has 4,900 databased observations from IMA forays for the past 23 years, representing 650 species. "Some 2,000 specimens (vouchers) were saved, but only about 300 of these have been accessioned into the permanent Field Museum of Natural History (F) collections," according to Leacock. "The rest are in herbarium cabinets with our other local research specimens waiting to be selected for packaging, barcoding, and transferring to the permanent collections."

Club-led Voucher and Sequencing Projects

DNA barcoding, or sequencing, is a powerful tool that probes the essence of a species' identity. It's so important that professional mycologists can barely publish research on fungi without including reference to DNA sequences. Some amateurs are setting up DIY (do-it-yourself) labs to extract and amplify small DNA fragments from the nuclear ribosomal internal transcribed spacer (ITS) region of the fungal genome, and then analyze results after a commercial lab has converted the amplified extract into a string of letters representing DNA base pairs. Amateur mushroomers Alan Rockefeller, Stephen Russell, Richard Jacob and Christian Schwarz have all given talks to clubs on the brave new world of DNA sequencing. (It's noteworthy that each of these individuals is significantly younger than the median age of NAMA members, if the prevalence of grey-haired baby boomers at NAMA forays is any indication.) Sequencing the ITS locus has been the standard for fungi for the past decade but new technologies are becoming more widespread that can sequence multiple loci at once. Rytas Vilgalys of Duke University says he will soon be able to provide multi-locus "next-gen" sequencing to mushroom clubs, possibly for equal or less cost than the current cost of ITS sequencing.



Richard Jacob

It should be clearly noted, however, that sequencing is not essential for doing valuable citizen science, nor is it a "slam dunk" for making species determinations. Traditional macroscopic and microscopic descriptions, high quality photographs, and accurate field information are no less important than they have always been to scientists studying fungi. Preserving specimens is more critical for high-quality citizen science than sequencing. When specimens are properly documented, dried and preserved in curated fungaria, scientists can examine them decades from now, and probably sequence them with more powerful technology than is presently available. In many cases a sequence will not provide a clear identification for many reasons. For example, if the type specimen of the species has not been sequenced – a common situation – it may be impossible to determine a mushroom's identity. Samples may be contaminated, reference data in GenBank may be erroneous, and a host of other problems. On the other hand, even if a sequence does not yield a positive species determination ("species hypothesis" is actually the technical term), valid sequences posted to GenBank are still extremely useful to mycologists working on phylogenies and ecology (Tom Bruns, personal communication).

NAMA Voucher Sequencing Program: In 2015, the NAMA Voucher Program (see above) added sequencing. Sampling of new collections for DNA barcoding was conducted using Whatman FTA Plantsaver cards. La Monte Yarroll (Western Pennsylvania Mushroom Club) did the sample collection at the 2015 Black Mountain foray and Stephen Russell (Hoosier Mushroom Society) at the 2016 Shenandoah foray. A first pass was made through the 2015 FTA card samples using Sanger sequencing, but the results still need to be proofread and edited before posting to GenBank, according to Rytas Vilgalys.

***Amanita* Projects:** Amanitas have been an early focus of sequencing, perhaps due to interest and encouragement from Rod Tulloss. The Western Pennsylvania Mushroom Club (see below) decided that half of their sequencing targets would be Amanita specimens. In 2016 the NAMA Board authorized a project led by Stephen Russell to sequence all the Amanitaceae specimens vouchered at NAMA annual forays over the past 20 years: 241 specimens of Amanita and 3 of Limacella vouchered between 1997 and 2015. Extractions and amplifications will be done in the Aime Lab at Purdue University, and sequencing will be done by Genewiz. The budget approved for sequencing is $3340, or about $14 per sample. Metadata will be posted to Russell's MycoMap platform and final sequences will deposited into GenBank and added to the original record reported on Mushroom Observer.

Western Pennsylvania Mushroom Club (WPMC): An excellent model has been created by WPMC under the leadership of club president Richard Jacob. Their website excels in thorough explanation and documentation of each step in collection, description and DNA barcoding specimens. The web page Introduction to DNA Barcoding provides a valuable tutorial on the process as well as links to record-keeping sheets. The club has created detailed binders that can be checked out by members wanting to engage in recording, vouchering and DNA barcoding. Currently, specimens are being sequenced at Duke University for the cost of labor and analyzed by Jacob; sequenced specimens are also stored at the Duke University Herbarium (DUKE). WPMC used the DNA barcoding work and a web-based bolete synoptic key in a project called the Northeast Bolete Consortium (see above). A key challenge to club-led mycoflora projects is illustrated by the fact that WPMC is keeping its extensive specimen documentation in a local database because critical web portals do not communicate with each other.

Southeastern Clubs: My colleague Ton Tran and I tested out the WPMC protocols on 12 haphazardly selected specimens collected during the annual Oconee State Park (SC) Foray in October 2016. The foray includes three southeastern clubs: our Mushroom Club of Georgia; Asheville (NC) Mushroom Club; and South Carolina Upstate Mycological Society. Observations are published as Species List 973 on Mushroom Observer. There is no better way to gain an appreciation of the many moving parts and challenges involved in this work!

Fungus Federation of Santa Cruz (FFSC): The most extensive club-led vouchering and sequencing project to date, along with an elegant website and Youtube videos, is that of the Santa Cruz Mycoflora Project (SCMP; www.scmycoflora.org), created by the Fungus Federation of Santa Cruz (California). Project leader Christian Schwarz views the project as "using citizen science to create a two-way flow of information between amateur naturalists and professional scientists … and to foster communities with a shared love of nature." The goal of SCMP is to create an Internet-based mycoflora of all the macrofungi in Santa Cruz County, based on vouchered and sequenced specimens. They have already identified around 1,000 species, and estimate that there may be 2,000 to 3,000 total species. FFSC allocated $15,000 for DNA sequencing in 2014. As of June 2016, 500 vouchered specimens had been processed and sequenced. According to Henry Young, "Not all them were successful for a variety of issues completely normal to the process, but we had >90% success rate," with considerable volunteer effort, along with intern labor, to creating a fungarium at the natural history

Christian Schwarz

museum at the University of California at Santa Cruz.

The SCMP website is the most elegant club mycoflora site I have viewed to date. Webmaster Adam Ryszka created it from scratch with the idea it could be used as a template for other clubs (contact Adam at drcarparts@gmail.com). In the Species Index section on the SCMP website, each genus link leads to a page with links to MycoPortal and Mushroom Observer. The MycoPortal link shows all vouchered material for that genus in official fungaria reported from the county, while the Mushroom Observer link shows all observations for the genus from the county (good photos but few vouchers). For example, the SCMP web page for Amanita says that "approximately" 21 Amanita species have been recorded from Santa Cruz County. The link to MycoPortal shows 88 specimens in various fungaria (some collected more than a century ago) while the link to Mushroom Observer shows 292 contemporary observations from Santa Cruz County. Such external links are simple devices that any club could readily create on their own websites. The Western Pennsylvania Mushroom Club uses a similar approach in its Mushroom Catalog. WPMC's website also has an innovative section on Species List Visualizations.

But updating static websites is tedious work, according to Schwarz. Stephen Russell's MycoMap aims to automate pulling all internet observations into a common platform for use by the Mycoflora 2.0 Project (see below). This will facilitate the creation of club species lists and geographic-based mycofloras.

Missouri Mycological Society (MOMS): The MOMS web page, Voucher Specimen List, provides another model for club websites. The page lists links to 155 specimens (different species), each with voucher information including multiple photographs, micrographs, voucher slips, collection information, spore descriptions and, in some cases, reference (though not yet links) to DNA barcode information. The New York Botanical Garden has agreed to take them and make the data available online through their website and MycoPortal. The club allocated $5,000 for training Brad Bomanz to do the DNA sequencing at Missouri Botanical Garden; 155 specimens have been sequenced and funds remain for another 95 specimens. At this writing sequences for five specimens have been posted to GenBank (e.g., Sarcoscypha occidentalis), and Brad is working on posting the remainder to both GenBank and the club web page.

Stephen Russell

Hoosier Mushroom Society (HMS): The long-term goal of HMS is to create a vouchered and sequenced mycoflora for the State of Indiana. The club currently has more than 1,000 individual specimens vouchered and sequenced. Club president Stephen Russell, who also chairs NAMA's Mycoflora Committee, is developing an ambitious web hub for mushrooms called MycoMap (www.mycomap.com), currently in beta mode. MycoMap aims eventually to be the "catch all mycological database/platform" described by Halme et al. (2012): a one-stop shop for uploading and tracking mushroom specimens, as well as providing integrations with essential datasets including Mushroom Observer, iNaturalist, MycoPortal, MycoBank, Index Fungorum, Discover Life, Encyclopedia of Life, UNITE, and GenBank. MycoMap even has a smartphone app (in development) designed to be used on forays. A novel element is that Russell aims to conduct environmental DNA sampling of soil, wood, and tree roots, with the environmental dataset forming the "backbone" list of species they are looking to find in the state.

Oregon Mycological Society (OMS): OMS's Mycoflora Working Group aims to identify, voucher and sequence at least some specimens found during club forays. The Group is led by Joe Cohen, who is also a developer for Mushroom Observer (MO) and species lists are posted to MO. Of some 1,200 observations, 11 have been sequenced in cooperation with the Forest Service Interagency Special Status/Sensitive Species Program

(see MO Species List 965). More than 100 dried specimens are kept at the homes of club members. The Mycoflora Working Group has a budget of $500 per year, most of which is anticipated to be used for sequencing.

Puget Sound Mycological Society (PSMS): PSMS is the largest mushroom club in the US. While the club has not started sequencing, they donated $2,000 to the Santa Cruz Mycoflora Project to help the latter gain experience with sequencing that will be useful to all clubs. The club's identification coordinator, Danny Miller, is currently the main programmer for MatchMaker (see next). Such keys are important components of mycofloras. Daniel Winkler is leading a new project to voucher macrofungi from Bridle Trails State Park (195 ha).

Pacific Northwest Key Council (PNWKC): The Key Council was created in 1974 as an invitation-only group of experienced amateur and professional mushroomers whose purpose is to create field keys to the fungi of the Pacific Northwest. The major result is the set of printable keys, available on the South Vancouver Island Mycological Society (SVIMS) website, to many Pacific Northwest fungi. Another resource is MatchMaker, a mushroom identification application for the entire Pacific Northwest with both synoptic and pictorial keys. Developed by Ian Gibson of SVIMS, the application can be downloaded free from the SVIMS website. Several years ago a decision was made to start vouchering and sequencing finds. But that was "more of an aspiration than a reality," according to PNWKC member Joe Cohen. Council president Paul Kroeger put it this way in an email to Joe Cohen, illustrating a key challenge for all mushroom clubs:

"I recall that at certain forays we attempted to voucher all taxa found when we had collecting permits in a National Forest and the local Forest Service desired it and assisted with documenting and disposition of the preserved specimens. The task is a daunting one and involves much labor. The logistics of actually processing all the material within a weekend is a real problem, and involves enormous amounts of follow-up work. There are limited numbers of herbaria able and willing to accept such large collections."

Arizona Mushroom Society (AMS): Vouchering and sequencing at AMS is mainly due to one motivated member, Terri Clements. She is working with the Gilbertson Mycological Herbarium (ARIZ) at the University of Arizona to voucher and sequence 150 specimens currently stored at her home and posted to Mushroom Observer (MO). The club encourages all members to create a MO observation before vouchering and to note the MO number on the voucher. Last year the club paid $212 to get eight *Morchella* specimens sequenced in Spain, and has allocated $250 for sequencing next year. Notes Terri: "Our small first effort resulted in two significant findings which are indicative of what citizen science can bring to the table. The eight specimens turned out to be seven species of *Morchella* that had not yet been documented from Arizona. And one of the specimens is a new species [confirmed by Kerry O'Donnell] that will now get a name."

San Diego Mycological Society (SDMS): SDMS has a web page, Mushroom Barcoding Project. Observations are not posted online; however, a March 2014 presentation said that 70 specimens had been vouchered at the San Diego Natural History Museum and sequenced by the International Barcode of Life project at the University of Guelph in Ontario, Canada.

Canadian Clubs

In the course of researching this article I became aware of an impressive amount of fungal citizen science activity in Canada. It's worthy of a separate article. Making no attempt to be comprehensive, I'll only mention several items of interest here. (Mexico has no amateur clubs and all sequencing is done at universities, according to Alan Rockefeller who collects extensively there.)

MycoQuébec's website is one of the best resources for mushroom identification in North America, with detailed descriptions of 2,958 species found in Québec Province and 20,365 high quality photographs imported from Flickr. They also have a (static) smartphone app, *La fonge du Québec*. "MycoQuébecis doesn't represent a club in particular, but seeks to involve all mycological clubs and independent amateur mycologists (professional are welcome too)," according to Renée Lebeuf. Several members have large personal fungaria with hundreds to thousands of specimens and numerous collections have been deposited in Université de Montréal's Centre sur la Biodiversité (many of which appear on MycoPortal).

British Columbia has several strong clubs. Oluna and Adolf Ceska, members of the **South Vancouver Island Mycological Society**, have collected, recorded (on Mushroom Observer) and vouchered about 3,500 specimens, of which 1,166 species come from a 75 ha area that was intensively sampled over a ten-year period – a model for citizen science projects. Victoria BC is also home of Ian Gibson, the original developer of MatchMaker (see above, PNWKC).

The **Alberta Mycological Society** has some 600 members in a province larger than California with no professional mycologists. Since 2005 they have been gathering all existing mushroom records, many vouchered, in a central website called Alberta Fungal Database. The club vouchers many specimens on forays (the default fungarium is Department of Agriculture in Ottawa). "Anything that is vouchered is sequenced," according to past-president Martin Osis. The club is currently adding DNA sequence data to its web database.

Foray Newfoundland and Labrador recently uploaded collection data to MycoPortal for 2,100 specimens from five years of forays (2011-2015). MycoPortal noted: "As one of the first amateur mycology groups to send us its data, we are pleased to see your high standards for collecting, identifying, and recording appropriate specimen information" (Kuhn et al., 2016).

Challenges

Club-led projects described above have faced similar challenges that must be addressed if mushroom citizen science is to become widespread. Key operational challenges fall in three categories: documentation and data management, vouchering, and sequencing.

Documentation and Data Management: For specimens to become valuable to science, documentation of morphological and ecological data is essential. Good photographs of fresh specimens and recording features that are lost upon drying (such as taste and odor) is important, as are micrographs. DNA sequences can be useful for identification but specimens that are otherwise well documented will still be valuable to future mycologists who can get genetic information from dried specimens.

A critical data management issue that needs to be solved is creating an easy process for sharing multifaceted observations with key Internet websites (modern mycofloras should be Internet-based). The problem is that there are multiple web portals that do not communicate easily or at all with each other. One web portal specializes in US fungaria records (MycoPortal), another keeps DNA sequences (GenBank), and several support uploading photo-rich observations, including Mushroom Observer, iNaturalist, Flickr (preferred by Eastern Canadian clubs), and Discover Life, in addition to club websites. (Facebook and Yahoo groups are used for sharing and identifying fungal finds, but those sites are not designed as databases so they do not function as repositories.) Mushroom Observer is dedicated to fungi so it has the largest community of expert mycologists who can help with identifications, but Mushroom Observer lags behind some other sites, especially iNaturalist, in functionality for taxonomic databasing. What's needed is the capability to upload multiple records to one site; have that information propagated to other key sites via a unique identifier; and have additional information (for example, the addition of a DNA sequence or fungarium accession number) update on all linked sites.

Vouchering: Curating specimens at established fungaria (those accessible to international scientists and likely to be around a long time) has labor, equipment and space costs. These costs are difficult to assess, vary locally and are long-term investments; but they are real. A key issue for amateur mycologists is the long time to accession specimens and get catalog numbers that clubs can link to their observations. Several cases were noted above of club specimens being submitted to fungaria but not accessioned, even after years. (due to lack of funding)

Sequencing: DNA sequencing costs, compared with vouchering costs, are upfront and easier to calculate. Of the three steps involved in DNA sequencing, step 1, extraction and amplification, can either be done locally or out-sourced; step 2, sequencing the extract, is generally out-sourced to a specialized lab with expensive DNA sequencers; and step 3, analysis of results, can be done locally by tech-savvy people using one's own computer and public Internet databases. Extraction and amplification (step 1) can be done in a DIY club lab for about $5 per specimen, if you don't count the cost of labor or initial cost of lab equipment.

A commercial lab is needed for the actual sequencing (step 2); that reportedly costs about $5-$8 in California (Alan Rockefeller, personal communication). Commercial labs can also do both steps 1 and 2, for around $30 per specimen currently. Clubs have used MCLAB in California (mclab.com) and ALVALAB in Spain (alvalab.es) which specializes in mycology. The Osmundson lab in Wisconsin is willing to take on sequencing club vouchers at cost. And technology is constantly evolving. As noted above, Duke's Rytas Vilgalys is developing multi-locus next-gen extraction and sequencing that he hopes to offer to clubs for $10 per read. Stephen Russell is working to make his MycoMap platform provide an analysis pipeline (step 3) where users can upload their raw sequence files and get an analytical report that includes phylogenetic trees from reference datasets.

Selected Club Expenditures for DNA Sequencing

MUSHROOM CLUB	AMOUNT
Fungus Federation of Santa Cruz (500 specimens)	$15,000
Missouri Mycological Society	5,000
NAMA Vouchering & Amanita Project	4,300
Hoosier Myshroom Society (for 2016)	2,000
Puget Sound Mycological Society (to FFSC, one time)	2,000
Western Pennsylvania Mushroom Club (500 specimens)	1,000
Oregon Mycological Society (for 2017)	500
Arizona Mushroom Society (for 2017)	250
Mycological Association of Washington, DC (for 2017)	200

It should be noted that vouchering and sequencing are starting points rather than end points for mushroom citizen science. As vouchering and sequencing become more common practices, the most avid amateurs may be drawn into advanced taxonomic projects like finding and sequencing neotypes for missing type specimens, researching old taxonomic literature, and describing and publishing new species. Others will be drawn to answering ecological questions.

Mycoflora 2.0 Project

Our review of club activity convinces us that interest in citizen science is widespread and the time is ripe for developing simple, standardized protocols and workflows for vouchering and sequencing, and for providing timely feedback to collectors. A group of amateur and professional mycologists is planning a pilot citizen project to develop such protocols so that any mushroom club -- or organization such as Radical Mycology -- that wants to do citizen science can do so efficiently and inexpensively. Our plan is to start with seven NAMA clubs and academic partners in different regions of the United States in the fall of 2017, with the goal of making processes created available to all serious amateur mycologists. Collection and sampling strategies will be developed in consultation with expert mycologists so that vouchering and sequencing effort is focused on filling data gaps. (For updates visit the Mycoflora 2.0 Facebook group.)

Data management will be based on a unique identifier (url or barcode) for every specimen which will link all components of each observation from all websites, including MycoPortal and GenBank. Several clubs have access to "established" fungaria in their states or regions; more will need to be found and protocols for submitting specimens developed. During the pilot phase, clubs will upload documentation and photographs to any platform that databases individual observations (including Mushroom Observer and iNaturalist). Experts will review observations and help determine which should be vouchered and sequenced. DNA "smash cards" will be sent to Duke University for sequencing (see next page).

MycoPortal will be the final destination for herbarium data and GenBank for sequence data. Data standardization, expert validation and creation and integration of the end floras will be done on MycoMap. Observation photos and data will be permanently archived on DiscoverLife.

Sequencing will be done, initially at least, at Duke University, in Rytas Vilgaly's lab. At the outset the single ITS locus will be sequenced, but eventually Vilgalys plans to make multi-locus "next-gen" sequencing technology available to the project. Whatman FTA Plantsaver cards (a.k.a. "smash" cards) will be provided to participating clubs or individuals, who will only need to take tiny tissue samples from specimens to be vouchered, smash the card with a hammer, and mail the cards to the central location. Our goal is to enlist academic mycologists to help raise funds so that sequencing, analysis and posting results on GenBank is done for all clubs at little or no cost, thereby valuing and integrating the contributions of amateurs into professional mycology (see next section). We are currently looking into funding from the National Science Foundation (for a Research Coordination Networks grant or writing in citizen science outreach components to new research grants) as well as to clubs, organizations and other sources.

Roles of Amateur and Professional Mycologists

Engaging amateur mycologists in the Mycoflora 2.0 Project is critical because there's simply no way that academically trained professional mycologists alone can create a North American mycoflora. For one thing there are simply not enough of them. There's been a significant waning of funding support for taxonomic research over the last several decades (Wheeler et al., 2004), resulting in a steep decline of professional taxonomists (Pearson et al., 2011). Mycology is no exception. And compared with botanists there are considerably fewer professional mycologists, and far more species of fungi than plants. Combining both factors, Bruns and Beug (2012) calculated a ratio of organisms to scientists that is conservatively 30 times worse for fungi than for plants. As academically trained professional taxonomists become rarer, the importance of self-supported expert amateurs increases. Vellinga (2013) noted that in Europe "in the last 10 years the number of species described by non-professional mycologists is greater than the number of species described by people who have mycology as their profession."

The role of academic mycologists also needs to change. Pearson et al. (2011) note that the decline of all fields of taxonomy means that surviving taxonomists need to work more closely with expert amateurs. Virtually all taxonomic fields started out dominated by amateurs but "over time theoretical and institutional developments lead reliably or even inevitably to the exclusion of expert amateurs" (Pearson et al., 2011). As taxonomy transitions "out of the museum and into cyberspace" opportunities are opened up for citizen scientists to engage and make substantial contributions. **Besides providing technical support, academic mycologists could solicit funding from their traditional research sources (primarily National Science Foundation in the US) for DNA sequencing and fungarium space for specimens collected by citizen scientists.** Other actions suggested by Pearson et al. (2011) include: (1) "writing grant proposals that are more likely to be funded by a wider range of private and government agencies through emphasizing support of youth education and cost-effective 'pro-ams' i.e. (professional-amateurs, "serious and committed citizen scientists who function at the level of some professionals but are not paid for their work"); (2) recruiting and mentoring amateur enthusiasts; and (3) sponsoring workshops and symposia in which professionals and pro-ams can interact and socialize with one another." For more on the economic value of 'pro-ams' see Leadbeater and Miller (2004).

It seems clear from activities described here that many amateur mushroomers are ready to make mushroom collecting a more scientific hobby. Harnessing the enthusiasm of amateurs through mushroom clubs and other organizations to do high-quality citizen science can not only help professional scientists, it can inspire members of the broader public to understand and want to conserve nature. With appropriate coordination, development of protocols, cyberinfrastructure, and some external funding, amateur mycology could become a poster child for high-quality citizen science. The results will benefit both amateur and professional mycology, while advancing taxonomic, ecological and conservation science.

Acknowledgments

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Artist Frits Ahlefeldt-Laurvig granted the Mycoflora 2.0 Project permission to use his watercolor of "The Wood Wide Web" as its official logo.

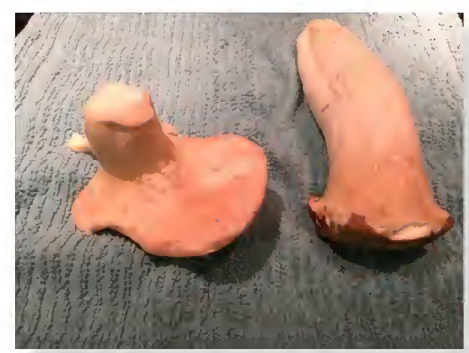
Meet the Nebrodini Mushroom

By Barbara Ching

If I never heard the term "pot hunter" again I would be a much happier amateur mycologist. Mushrooms are delicious and it's a thrill to find a flush of morels or glowing *Laetiporus cincinnatus*—so why scoff at such joy? It's a good primal instinct. Finding, identifying, cultivating, and making them taste good feeds us, and the sharing the ways it can happen could feed more of us. We as a species should eat more mushrooms, just as we should eat more plants—even if we aren't going to find enough of either on a foray. That's why we cultivate.

The story of the over-hunted, endangered delicious *Pleurotus nebrodensis* shows how the hunt/ eat/ cultivate/ preserve then eat some more cycle happens. This oyster mushroom species grows wild in an ever-diminishing habitat in the Nebrodi mountains in northeast Sicily—in fact, the International Union for Conservation of Nature (IUCN) declared the mushroom "critically endangered" in 2006. In 2008, Gourmet Mushrooms Incorporated began cultivating the mushroom in the United States and sells it under the trademarked name Nebrodini Bianco™. (It's cultivated in other parts of the world, too.) I discovered it in a chain grocery store in a Mycopia "specialty trio" box, nestled in with velvet pioppini and forest nameko. According to Justin Reyes, Director of culinary sales and marketing for Gourmet Mushrooms and member of the Sonoma County Mycological Association, the company has doubled the production of Nebrodini over the past 18 months—to "a few thousand pounds a week."

Even though Nebrodini look like, and are closely related to the Trumpet Royale (*Pleurotus eryngii*), they have a much better texture. The King Oyster (on the right in the picture below) is 8 inches long and the stem is nearly the entire mushroom. The Nebrodini measure 4.25 in. long, mostly stem, too. But the Nebrodini cap is 5 1/8 in wide to the King's 3 3/8. The Nebrodini cap has a variable thickness, but at 3/8-5/8 inch thick, it's at least twice as thick as the King Oyster. This ratio also explains the much more pleasing texture of the Nebrodini—the cap is large but thin. The first time I tasted them, simply sautéed, they reminded me of Weiner schnitzel--specifically, of a very tender schnitzel I ate years ago in Vienna, at Café Landtmann, Sigmund Freud's favorite café.



I'd rather eat this mushroom than eat meat, though, and one of the best things mushrooms can do for earth and us earthlings is to take meat's place. Big clean tasty mushrooms make it so easy--Chicken of the woods, Maitake, and now Nebrodini can do that. (Portobellos don't, at least for me. They should be nicknamed mud pies.)

I ordered a 3 pound bag of Nebrodini for a holiday treat. Opening the 3 lb bag, I was struck by an intense, citrus/ anise scent-- like Belgian blonde ale and lots of other things I love--black licorice, caraway seeds, earl grey tea. Every time I opened the refrigerator while the mushrooms rested in there, I got a blast of this, too. No fridge full of Maitake or Chicken of the Woods has ever greeted me like this, and this aroma was completely masked in the crowded Mycopia mixed box that introduced me to Nebrodini.

This scented surprise decided how I would cook them. The Mycopia website advocates grilling--and this is a good cooking method in the summer even though the smoke and char smothers the scent (http://blog.mycopia.com/?cat=12). I'd serve the olive oil marinated and lemon juice sprinkled grilled caps on salad greens --in which case my teenage daughter wouldn't eat them and some of us would end up eating fried tenderloin sandwiches (aka pork schnitzel) at the drive-in restaurant on the edge of town later that night.

At any rate, the largest mushroom tops would be perfect for homemade schnitzel. I microwaved a few of them with a bit of water to make sure they were thoroughly cooked since I worried that the coating would cook a lot faster

than the mushroom although I did set one aside to see if the pre-cooking was necessary. I succumbed to the fast food temptation by using Knorr "Wiener Schnitzel Fix". Easy--just add water. The coated mushroom caps looked like pancakes. So did the cooked mushroom caps. Maybe I should have pounded the mushroom caps or sliced them thinner? Even so, my husband liked them a lot and had some more for breakfast the next day. I thought they were okay. Not great. The one that I didn't pre-cook in the microwave was better but my Viennese memory is way better than that one, too. Is this Knorr's fault?

Would beer batter be a better fix? The mushrooms smell so much like one of my favorite local beers—Peace Tree brewery's blonde fatale. I made a basic beer batter with this Belgian style ale, rolled the mushroom pieces in dried puffball powder before coating them in batter and dropped them in some 375 degree peanut oil. (I use a big wok for deep frying). The beer-battered schnitzels look like fried animal crackers. Would Freud say that this comparison shows that I really want veal? These Nebrodini are delicious—the batter is crisp; the interior is tender, and the flavors of both components complement each other well. I say that this is exactly what I wanted.

But I also wanted something I had never tasted before. The best thing I made was a hearty soup that put the Nebrodini scent and pillowy texture in a spoon. For the broth I horizontally cut a fennel bulb in three roughly equal segments: the bulb, to be sliced into the soup to thicken it, the feathery stalks to make a broth, and a few fronds for the final garnish. Everything but the garnish pieces went into in a crock pot with a whole peeled onion, and some of the toughest Nebrodini stems. I added 2 quarts of water and a few pinches of salt and let it cook on low overnight. This is a fat-free, vegan broth so it doesn't have the silky texture and body that marrow gives to meat broths. To create body, I strained out the mushroom stems and vegetables then pureed the vegetables and stirred them back in the broth. I reduced the liquid to 6 cups –in a big saucepan on a burner. To finish it, I add ½ cup of diced canned tomatoes. This formula makes about 6 servings of "Eau de Nebrodini" soup. For each serving, put about ½ cup of sliced Nebrodini caps and stems in a bowl along with some chopped fennel fronds. Cover with steaming hot soup. By the time you get the bowls to the table, you'll see the mushroom pieces floating in soup like dumplings or thick egg noodles.

Foraged, then cultivated and eaten, the Nebrodini connected my memories of food I no longer want to eat—veal—to my cravings for foods I do want to eat. Seeking the Nebrodini may be pot hunting but like most pot hunting, I'd argue, it bites off more than one person can chew. In an association like NAMA, we pass it on, too.

Editor's Correction: In the March-April issue of *The Mycophile*, authorship of the article on the Paul Bunyan Club was mistakenly credited to Gene Kremer who emailed it to me. The author was Mark Chekola.

Mycology and Citizen Science in Europe: an overview

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Introduction

In the course of researching mycological citizen science in North America, Bill Sheehan (2017, this issue) contacted me about activities in Europe. This article provides a general overview of current practice illustrated with examples from Denmark, Norway and the United Kingdom & Ireland.

Background

The European Mycological Association (EMA; http://www.euromould.org/) seeks to provide a knowledge exchange forum for mycologists (mainly professional) from all European countries. They work closely with organizations like the European Council for the Conservation of Fungi (http://www.wsl.ch/eccf/) and the International Mycological Association (http://www.ima-mycology.org/) on initiatives such as IUCN Red Lists for fungi (http://www.iucnredlist.org/). EMA research identified mycological associations in almost every European country but found that the level of citizen science engagement was highly variable.

The UN Convention on Biological Diversity (https://www.cbd.int/) has driven the introduction of national strategies for the conservation and sustainable use of biological diversity in Europe in recent decades, influencing policy, legislation and funding (https://www.cbd.int/). Many European countries have or are now in the process of setting up national databases and these in turn are beginning to feed into (and draw from) the Global Biological Information Facility, GBIF (http://www.gbif.org/). GBIF is currently the main international repository for biological records and is able to hold and process vast amounts of data, providing access to records of fungi as well as plants and animals at a global scale. Software for online recording schemes (often linked directly to the national database and GBIF) has developed rapidly in recent years, with many interactive websites hosting photographs and providing mapping facilities and discussion forums that encourage and support the digitization of field observations and knowledge exchange between participants. Associated metadata provides further information on data sources and validation procedures.

Sequencing

The International Nucleotide Sequence Databases Collaboration (http://www.insdc.org) is the main facility for sequenced data and GenBank (https://www.ncbi.nlm.nih.gov/genbank/) the most popular route for depositing data. Molecular studies are largely the domain of the research community at present. However, an international initiative for DNA analysis, UNITE (http://www.unite.ut.ee), led by the University of Tartu, Estonia since 2003, can provide ribosomal DNA ITS sequences free of charge to any mycologist interested in obtaining molecular data for identification purposes and has many active European participants. Sequences, once generated, are automatically compared with accession species on a range of public databases, such as GenBank, to find matching sequences that are also linked to metadata, photographs and vouchered specimens from museums and private collections. Species data are clustered based on similarity thresholds (97-99%), designated as a species hypothesis and assigned a data identification number (a DOI). This public database currently holds 741,222 sequences covering 68,746 species hypotheses. The site provides links to a wide range of information and expertise helping to explain and support molecular studies. Some European countries are also working with the International Barcode of Life project in Canada (http://www.barcodeoflife.org/content/about/what-dna-barcoding) to sequence collections.

Citizen science

Citizen science (CS) is a broad term but generally refers to voluntary work that has research value. It is important to recognize that the term can apply to any citizen contributing to research but it is also widely used in the context of voluntary activity by formalized groups and societies (including professionals) such as mycological field clubs.

The worldwide web, mobile phones, digital photography and GPS have facilitated this development (Dickinson & Bonney, 2012; Davies et al, 2016), increasing participation in many disciplines, particularly the natural sciences, and providing opportunities to study our natural heritage on a previously unimaginable scale.

Citizen scientists, particularly those new to observing and recording wildlife and who are not affiliated with a club or society, can participate in many ways. Wildlife photographs can be submitted to generalist sites such as iSpot (http://www.ispotnature.org/communities/global), iRecord (http://www.brc.ac.uk/irecord/), iNaturalist (https://www.inaturalist.org/) and, specifically for fungi, to Mushroom Observer (http://mushroomobserver.org/). Help with naming species is provided by experts (often from clubs and societies) who in turn gain new records, wider spatial coverage and in some cases access to specimens. The Open Air Laboratories CS project (http://www.opalexplorenature.org.uk) developed habitat surveys (including one on lichens and air pollution) that have generated data from over 30,000 sites across the UK and introduced many thousands of citizens to the process of biological recording and its relevance to nature conservation. Many national biological recording databases are open to the general public too.

We formed the European Citizen Science Association (ECSA) in 2013 (https://ecsa.citizen-science.net/) in recognition of the substantial growth in this area. ECSA currently has representatives from 28 European countries contributing to CS science and policy development and the design and delivery of CS programs across Europe.

Recording fungi in Europe

One of the most active European-level mycological organization for field clubs and individuals is the European Confederation of Mediterranean Mycology (http://mycocemm.pagesperso-orange.fr/index.htm), founded in 1993. CEMM brings together mycologists from Spain, Italy, France and Portugal (and further afield, such as the Norwegian Mycological Society), with over 6,000 members. CEMM organizes an annual convention in different locations in the Mediterranean region bringing together delegates (200+) for field trips, lectures and networking. Members' interests range from taxonomy to gastronomy and includes both professionals and amateurs. There are many other regular, regional meetings across Europe such as the Nordic Congress, as well as specialist habitat (e.g. alpine) and taxon groups bringing mycologists together on a regular basis, and numerous groups working on national mycobiotas and selected genera. Vouchers tend to be deposited in natural history museums and other research institutions where they are gradually being digitized. Guided by CETAF (http://cetaf.org/), this work is helping to make historic collections (including types) more accessible.

Denmark

The Danish National Society for Mycology (www.svampe.dk) was formed in 1905 and has a membership of over 2000 with annual fees of 150 DKK (21 USD). The society, run by volunteers, involves professional and citizen scientists. The Society organizes more than 100 one-day forays per year plus weekend and week-long events, publishes a popular journal and promotes mycology.

An ambitious project known as the Danish Fungal Atlas was launched almost a decade ago (http://svampe.databasen.org/). The project was designed and led by leading professional Danish mycologists who already had a very good understanding of the diversity of fungi nationally but who recognized the spatial limits of their data and, like the Mycoflora 2.0 initiative, required additional manpower to help compile a comprehensive, representative national mycobiota. A citizen science project was established (with charitable funds) involving professionals, citizen scientists and schools. It was found that the effort involved in working with the latter could be better used to support and train amateur mycologists. There are currently 1700 registered recorders posting data on the Danish Fungal Atlas website.

Most records arising from fieldwork are entered directly into the Fungal Atlas database and once validated transferred to GBIF, but a small number are also submitted to a national privately run all-taxa platform (www.fugleognatur.dk). The validation system used by the Fungal Atlas has three levels: (i) no validation needed (widespread, common and distinct species); (ii) photo needed (characteristic but less common species); (iii) voucher specimen to be submitted for validation (the rest). About 80% of the known Danish species were coded with some validation

requirements, but around 80% of the data entered in the database actually represented common and characteristic species with no validation requirements. The validation system is changing to make it more interactive. Participants will be more involved and their skill levels assessed and utilised in the validation process. In addition, species-record probability tests will be applied based on the time of the year and the taxon-specific overall frequency in Denmark. Vouchers are submitted to the Danish Natural History Museum fungarium which holds nearly 50,000 collections (currently being digitised and submitted to GBIF). High quality sequencing facilities are available and used as necessary. At the present time sequence data are not presented on the Atlas website and it is likely that in the future they will be stored on UNITE with links to the Atlas.

The project has generated over 250,000 records to date taking the total records on the Danish Atlas database to nearly 600,000 (including lichen forming fungi). The project has 414 very active recorders, of which 109 submitted more than 100 records, while 45 submitted more than 1000 records. The most active user alone submitted almost 16,000 records. The website has no geographical boundaries and can be used by countries that are in the early stages of recording their fungal biodiversity.

Norway

The majority of fungal records are generated by members of the Norges Sopp og Nyttevektsforbund, (NSoN), the national mycological and edible/useful (e.g dying) plant association (http://www.soppognyttevekster.no/). There is also a small number of non-affiliated local clubs (https://oosn.no/). Combining mycology with botanical interests facilitates regular field meetings. The Society has a membership of 4,300, fees of 400 NOK (46USD) and organizes one-day forays on a weekly basis as well as week-long field trips, events and two annual meetings. Many members are professional mycologists. The Society publishes two journals: *Agarica* is a peer-reviewed, research-focused publication covering all aspects of mycology; and *Sopp og Nyttevekster*, geared more towards a general audience. Members of the society are encouraged to become qualified 'mushroom controllers' able to check and name field finds at the end of a foray to ensure that poisonous species are not included in the edibles basket. A national mapping foray is organized annually, managed by SABIMA (https://www.sabima.no/), the umbrella organization for Biology Societies, which is also responsible for rare and Red List taxa and works in association with the Society and experts in each county.

Fungal records are submitted to the Norwegian online recording system, Artsobservasjoner, which is the same location for plant and animal observations in Norway (https://www.artsobservasjoner.no/). It is linked to the national database, Artskart and data are transferred to GBIF. The system was developed in association with Sweden, which uses the same software (http://www.artdatabanken.se/en/), but each country retains its own geographical boundary. The site is highly interactive with excellent mapping, metadata and community-driven participation software and is very popular. Help with identification is provided by the Norwegian Biodiversity Information Centre (http://www.biodiversity.no/). There is a built-in validation procedure and vouchers are not required for every record. SABIMA is responsible for quality control of Artsobservasjoner and the museums are responsible for vouchered fungal specimens (http://nhm2.uio.no/botanisk/nxd/sopp/nsd_b.htm). Between 10% and 20% of records are vouchered. Sequencing of wildlife in Norway is led by the Norwegian Sequencing Centre (https://www.sequencing.uio.no/). However, in recent years many thousands of the fungarium collections have been sequenced through the BOLD facility (http://biodiversitygenomics.net/projects/bold/), part of the Barcode of Life Data Systems project at the University of Guelph, Canada.

Norway and Sweden lead the field in terms of numbers of observations on GBIF across all taxa with the UK providing the largest number of records for fungi (including lichen forming fungi) worldwide.

Great Britain and Ireland

The British Mycological Society (http://www.britmycolsoc.org.uk/) was founded in 1896 and promotes all aspects of mycology through a range of activities including field meetings, conferences and education. BMS publishes three journals via Elsevier with citation scores. *Fungal Ecology* and *Fungal Biology* are peer-reviewed academic

journals covering all aspects of mycology from cell biology to genetics. Field Mycology is geared more towards the field mycologist with popular articles and high quality photographs. BMS has over 600 paid members with annual fees of £35.00 (42USD), 2500 followers on Facebook and 37 registered field clubs from across the UK & Ireland. The BMS database currently holds 2,083,352 records (about 15% of which are vouchered) covering more than 15,000 species (http://www.fieldmycology.net/frdbi/frdbi.asp). The majority of records are from members with a high level of expertise and are submitted electronically. A new BMS database (www.frdbi.info) will be launched this summer with more sophisticated search and mapping facilities, metadata, photographs, partly automated record validation procedures and data transfer facilities. It will be managed by Stuart Skeates (webmaster@britmycolsoc.info). The new site has a feature linking experts with citizens, similar to that found on Mushroom Observer. BMS data are transferred to the UK's National Biodiversity Network Database (NBN: https://nbnatlas.org/) and on to GBIF.

Most vouchers are submitted to The Royal Botanic Gardens Kew (http://www.kew.org/) which houses the world's largest collection of fungi (http://apps.kew.org/herbtrack/search), or to The Royal Botanic Gardens Edinburgh, Scotland (http://www.rbge.org.uk/). Some BMS members work at these locations and help to facilitate identification (including sequencing) and vouchering. Data from the former will be made available through GBIF this summer. A small number of other facilities hold collections and many collections are privately maintained.

The British Lichen Society (BLS) is the leading organisation for the study, conservation and promotion of lichen-forming fungi (http://www.britishlichensociety.org.uk/). Formed in 1958, the Society has amassed 2,264,357 records from surveys covering 2,366 taxa (including some basidiomycetes) dating back to the 18th Century. All records have been digitised with much of the work done by citizens supported by a small government grant. Data are available through the NBN and GBIF. As with BMS, members include professionals and citizen scientists working in a voluntary capacity. Vouchers are mainly deposited in the Natural History Museum (http://www.nmh.gov.uk) or held privately. Of the 2,000,000-plus fungal records held by BMS, only about 50,000 are of lichen-forming fungi.

Sequencing is not routinely offered to members by BMS or BLS directly, although research grants are available from both Societies. As with NAMA, many members are involved in projects to sequence their collections, often working with research colleagues. Clubs and individuals are exploring various options (Harries, 2016), from testing the prototype of Bentolab, a DNA extraction technique, to developing funding applications for larger-scale initiatives focused on sequencing private collections.

Conclusion

Fungi have been recorded in Europe for centuries. Many of these observations have arisen through citizen science, that is voluntary effort, and these data are now being digitized, submitted to national databases and on to GBIF thus making fungal records accessible on a once unimaginable scale. Progress is highly variable across Europe and whilst much has been achieved in recent years, each country works at its own pace and some are just starting the process of creating a national mycobiota. Many challenges lie ahead particularly in those countries where citizen science is a relatively new activity and online recording is in its infancy. Language can be a barrier to knowledge exchange but efforts are being made to bring nations together to share best practice. The European Biodiversity Portal (http://biodiversity.eubon.eu/) is one such initiative that seeks to provide a one-stop shop for data searches covering wildlife, habitats, genetics, climate, citizen science etc. and analytical tools.

It is recognized also that inexpensive, simple field sampling and large-scale, fast through-put, multi-loci processing facilities are required for comprehensive national mycobiota. In addition, storage and reference facilities for DNA samples will need to be established. These molecular studies, together with digitized field records and vouchered collections, will contribute significantly to research in taxonomy and systematics where so many families and genera remain poorly understood. Progress in all of these areas is being made. However, technology alone cannot resolve these issues; experienced mycologists are essential for the interpretation of these data. Funding to train and support them remains a major issue in much of Europe.

In closing I would like to thank Bill Sheehan and colleagues at NAMA for this opportunity to share current practice in citizen science and mycology in Europe and to recognize that we are facing many similar challenges in developing

national mycobiota.

Acknowledgements
I would like to thank Jacob Heilmann-Clausen, Tor Erik Brandrun, Urmas Kõljalg, Paul Kirk, Stuart Skeates and Janet Simpkins for their help with this article.

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Dickinson, J. L., Bonney, R. Eds. (2012) *Citizen Science: Public participation in environmental research*, Cornell University Press, Ithaca.
Davies, L., Fradera, R., Riesch, H., Lakeman-Fraser, P. (2016) Surveying the Citizen Science Landscape: an exploration of the design, delivery and impact of citizen science through the lens of the Open Air Laboratories programme. *BMC Ecology*, London
Harries, P. (2017) DNA and the Field Mycologist (Part 1), *Field Mycology*, Vol 18 Pg 21-23, UK

Registration for NAMA's Northwoods Foray in Wisconsin is filling up fast.

SEPTEMBER 7-10

Don't wait until it is too late to participate!

WILDACRES *AMANITA* WORKSHOP WITH DR. ROD TULLOSS

NAMA is offering members a unique opportunity to study the Amanitaceae at greater depth!

Dr. Rod Tulloss will hold a four and a half day seminar at Wildacres prior the Regional foray in September. The class will begin at noon on Sunday at a nearby location TBD, September 24 and move to Wildacres on Monday, continuing through Thursday, the 28th.

The emphasis of the seminar will be on the genetics of the *Amanita* family. Beginning with the focus on genes as a blueprint to be copied in a four letter alphabet, then moving through mutations, the genetic tools, terminology and applications for sequencing DNA, participants should develop the skills to do their own analyses and enrich their comprehension of this intriguing group. Some of the questions and problems of current methods of sequencing will be reviewed. Many of these techniques should be applicable to other fungal families, with consideration of the particular characteristics of each. Additionally, some field collecting and identification will be part of the course but of a secondary nature.

Attendees must be familiar with fungal microscopy, and able to bring their own microscopes, chemicals and equipment. Since Wildacres is closed on Sunday, participants will be responsible for their Sunday night lodging before moving to the retreat on Mon. All other costs are included in the registration of $250. The seminar is limited to eight members.

Please contact Glenda O'Neal with questions, or to register for this workshop. (423) 863-2742.glendakoneal@yahoo.com

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Congratulations to Dr. Gary Lincoff!

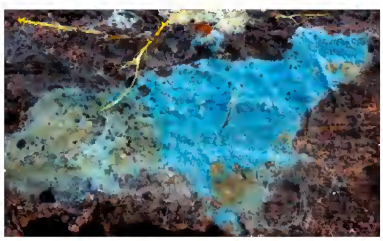
The Mycological Society of America (MSA) has selected Gary Lincoff to receive the Gordon and Tina Wasson Award. The Wasson Award recognizes people with non-traditional academic backgrounds who have made outstanding contributions to the field of mycology, or who have widely transmitted significant scientific or aesthetic knowledge about fungi to the general public. He will be recognized for his work and accomplishments at the MSA meeting Awards Ceremony taking place at the University of Georgia in Athens, July16-19, 2017.

Crust Fungi In and Around New York City

By Tom Bigelow of the NYMS

About 5 years ago the New York Mycological Society bucked against the prevailing notion that the mushroom season in the Northeast runs from June through November and began holding forays in New York City on a weekly basis, year round. We also started weekly identification sessions year round to go over our finds. The benefits of this practice have been twofold: it has stanched the ennui felt by most mycophiles during the "off season", and it brought to our attention the existence of a mycoflora that was previously unknown to most of us. One of the fungus groups that stands out during the fall, winter and spring months is the crusts (including, for the sake of this piece, stereoid fungi and resupinate polypores). In part, because there are fewer gilled fungi to be distracted by, and also because many crusts seem to prefer the cooler weather.

This group of fungi is often overlooked by mushroom hunters whose primary interest is dinner. They are often thought to lack the charisma of, say, a stately bolete (indeed, there is a dizzying array of crust fungi that resemble more a smear of whitish paint than anything else). But many are astonishingly beautiful, both macro and microscopically. A good many are even readily identified without a microscope. In the past several years, the NYMS has recorded approximately 75 species in the five boroughs. . . Several of the more striking examples follow:



Byssocorticium atrovirens

Byssocorticium atrovirens. This cottony crust turns up occasionally in New York City in the fall and early winter. There are several other blue/green *Byssocorticium* species, all of which have larger spores.

Phanerochaete chrysorhiza

Phanerochaete chrysorhiza. A common crust fungus, regularly found in New York City from summer through winter on oak and other hardwoods. The long orange rhizomorphs and spiny fertile surface make it easy to identify.

Porothelium fimbriatum

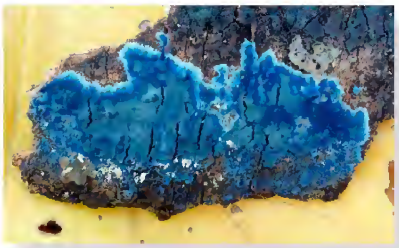
Porothelium fimbriatum. This fantastic polypore often resembles scattered cup fungi growing out of a cottony, fimbriate subiculum, often with long, wildly branching rhizomorphs.

Rigidoporus crocatus

Rigidoporus crocatus. An annual to perennial polypore. Successive pore layers grow on the previous years' growth in progressively smaller patches. It has a tough consistency and can easily be removed from the substrate with the tip of a knife. When fresh, it often has a surprising and pleasant smell of yellow cake.

Serpula himantioides

Serpula himantioides. Log Tripe. Most often found on conifer (we find it on white pine in the Bronx), it also turns up occasionally on hardwood. The convoluted, wrinkled surface has lilac tones that become yellowish brown as the spores mature. It has a white, gossamer margin with thin rhizomorphs. Copious yellowish-brown spores are often seen amassed on leafy debris beneath a fruiting.



Terana caerulea

Terana caerulea. While it is more common in the south, Juniper Perlis and I have found *Terana caerulea* in Great Swamp in New Jersey (the NJMA has a couple of records of it over the past 20 years, and the CVMA has found it as well). It was collected for the first time in New York City by NYMS member, Deb Klein, on November 13th, 2016 in Cunningham Park, Queens. The brilliant royal blue of this fungus is spectacular.

Xenasmatella vaga

Xenasmatella vaga. This beautiful and distinctive fungus is common from spring through late fall, found on a wide range of hardwoods. The cottony, fibrous mats, with fringed margins and long, branching rhizomormphs, are easily detached from their substrate. The colors range from white to bright yellow at the margin to brownish. The surface turns red in KOH.

Xylobolus subpileatus

Xylobolus subpileatus. Very common in the Great Swamp in New Jersey, we've only found it in one location in New York City: Alley Pond Park, Queens. Long time NYMS member Aaron Norarevian has seen it on the trunk of an old oak there for over 20 years. It causes white pocket rot and takes its time about it. As is the case wherever I see this fungus, the wood is rock hard and there is never any other fungus in evidence (except, on occasion, the more common *Xylobolus frustulatus*). The spores are ellipsoid, smooth, and amyloid.

A note on reference materials: The best manuals and reference works for crust fungi are from Europe. Luckily, many species that occur in Europe are also found in North America. Some of these references are pricey, but they are great investments for mushroom clubs interested in learning about crust fungi:

Bernicchia, A., Gorjón, S.P. *Corticiaceae s.l.* (*Fungi Europaei 12*). Alassio: Edizioni Candusso, 2010.

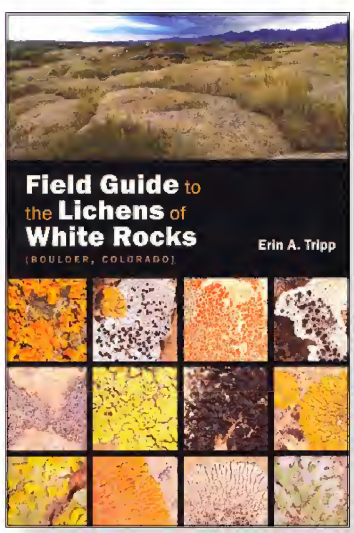
Breitenbach, J., Kränzlin, F. *Fungi of Switzerland, Volume 2: Non Gilled Fungi: Heterobasidiomycetes, Aphyllophorales, Gastromycetes*. Lucerne, Switzerland: Verlag Mykologia, 1986.

Hugill, P., Lucas, A. *The Resupinates of Hampshire*. London: The Tree Council, 2017.

Ryvarden, L., Melo, I. P*oroid Fungi of Europe (Synopsis Fungorum 31*). Oslo: Fungiflora, 2014.

The Corticiaceae of Northern Europe, Volumes 1 – 8 are available online at http://www.mykoweb.com/

Field Guide to the Lichens of White Rocks (Boulder, Colorado)



Erin A. Tripp
2016, University Press of Colorado (http://upcolorado.com/)
978-1-60732-553-6 (paper, v+170 pages)
$21.95 (paper) / $17.95 (e-book) / $5.99 (30-day e-book rental)

This focused field guide, which was produced in Boulder, Colorado, deals with the lichens that occur in a City of Boulder natural area (White Rocks Nature Preserve). The author, Erin Tripp, is assistant professor in the Department of Ecology and Evolutionary Biology at the University of Colorado located, naturally, in Boulder.

Attractive and nicely put together, the book starts with 15 pages of Introduction (Why Lichens? Lichen Biology: The Basics; Lichen Reproduction; Growth Forms; Substrates; Additional Remarks; and About the Guide); followed by the Field Guide (the species descriptions); an Appendix (Checklist of the Lichens of White Rocks), and Dichotomous Key to the Lichens of White Rocks; Glossary; Literature Cited; and Index.

Fifty-six taxa are described and illustrated, 41 of which are crusts and most of the others closely appressed foliose species. Descriptions are presented alphabetically and appear on the right-hand page. The species name is given, without authority, along with a common name, many of which appear to have been made up for the book. The text begins with a paragraph of helpful commentary, sometimes as much as a half page in length, that provides key distinctive features and comparisons with similar species. This is followed by very brief entries consisting of Chemistry, Substrate and Ecology, Distribution, and Literature citations. Chemical spot test reactions are given, but nowhere are they explained. While this will be no problem for someone who knows a bit about lichens, it likely will be confusing for others. Likewise, references to spore size and shape, and the presence of compounds disclosed through thin layer chromatography, will be of use only to more experienced users.

The main photograph for each taxon appears on the left-hand page. Each fills the entire page, with no margin. Nearly all are extreme close-ups. While this allows detail to be shown, I would have preferred a more typical approach, not quite so close up, and showing a bit of the surrounding rock surface to provide a sense of actual size, particularly because no scale is provided and there are no dimensions cited in the text. Color rendition is good and the images should prove useful for identification purposes. In many cases, a small inset photo is included, usually to provide an even closer view of specific structures such as apothecia.

Details of the presentation would have benefited from careful editing, including by someone familiar with geology and its terminology. There are quite a few typos. In places where the reader's attention is directed to a particular part of a photograph, the direction was written with reference to the photo in landscape orientation, but the photos are printed in portrait orientation. Sandstones are named for their texture and can have many chemical and mineral compositions. Thus they are not an example of a siliceous (not "silicaceous") rock as, for instance, there can be calcareous sandstones. Other geological terms, such as "formation," also are used incorrectly.

Although, to judge by the back cover text, the guide was intended for use by everyone from beginners to experienced lichen enthusiasts ("weekend naturalist and professional lichenologist" alike), I'm not sure it is all that "user friendly" for the uninitiated. In most cases, they aren't going to have access to microscopes, thin layer chromatography, etc. and the microscopic and chemical features are heavily used in the key, often as single features in a lead. Statements to the effect that a species is "impossible to confuse" or "cannot be mistaken for" are very misleading. Crustose lichens are not an easy group to work with and human beings have a seemingly limitless capacity for confusing even quite dissimilar things.

I am not in favor of force-fitting "common" names for organisms that most people are unfamiliar with, which includes lichens in general and especially crusts. Rarely do such names ever get widely used, even when they are good ones. So I have a hard time believing that names such as the following will make it into the general lingo — stool pigeon, Rocky Mountain sunburn (even though the species is described as "known primarily from Arizona to California"), flaming cowgirls, a textured dilemma, my old friend, eggplant in garlic sauce, volcanic kelp, backcountry pancakes, purple prose, and rib ticklers. Perhaps they are meaningful to the author, but will they really facilitate communication among other folks?

So who might want to buy this guide? White Rocks is a rare habitat for the region and the Preserve is closed to public access, other than by scheduling a staff-led tour or initiating a research project. The bulk of the species are crusts, which are notoriously difficult to work with and so are ignored by many in the small subset of the general population that has an interest in lichens. Thus, I'm not sure it will appeal to a general naturalist crowd. The strongest aspect of the book lies in its providing a detailed record of one group of organisms from the Preserve. All of the lichens so far recorded from the site are included, with photos tied to voucher specimens, and all taken at White Rocks even in cases where Tripp had better quality photos of a species, but taken at another site. As such it is an authoritative and valuable resource. So to me, the book probably will be of most use as a handy accessory text for Rocky Mountain licheneers with enough experience and courage to have begun to tackle the crusts.

Steve Trudell

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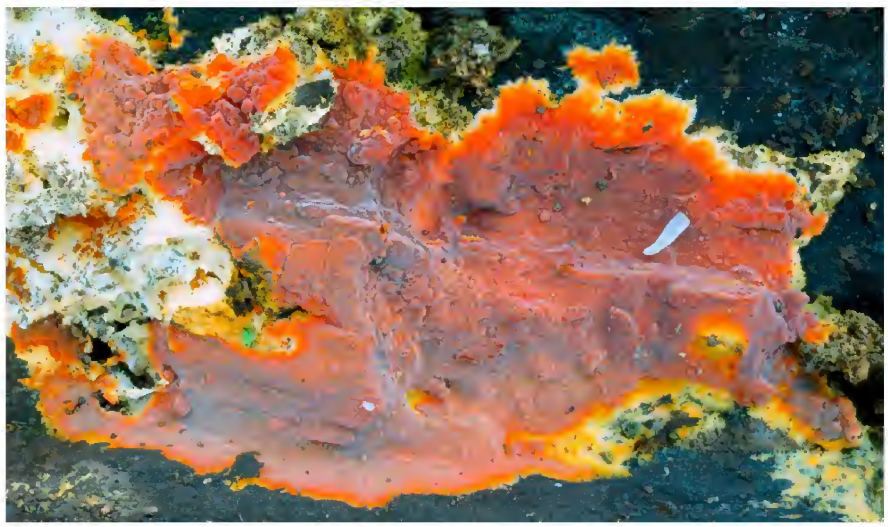
Mushroom of the Issue



Phlebia coccineofulva. The bright, electric colors (red, orange, gold) of this crust when fresh are second to none! Not yet observed in New York City, but found twice in Nassau County (just over the Queens border) and in Rockland County, across the Hudson River – each case in April.

Phlebia coccineofulva Photo and text by Tom Bigelow of the NYMS